22884

Title: **Innovative minus power lens and processing methods thereof**

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Technical field

Subject of this find is a myopic correcting lens for medium-to-strong to particularly strong prescriptions. In particular, the find concerns a finished or semi-finished lens and the processing methods thereof. "Finished lens" means a lens with both surfaces finished, whereas "semi-finished" lens means a lens with one surface finished.

New high index mineral or plastic materials are continuously being developed. Finished lenses, though premium cosmetics, are industrially produced to cater only for medium to low correction. People with high myopia require strong correcting lenses with a short radius of curvature and thick edges, which are difficult or impossible to fit in some eyeglass frames, thus restricting the selection of frames nearsighted people can choose among. In addition, heavy eyeglasses are less comfortable and attractive. Cosmetics is further penalised by the "coke bottle" effect which is visible at the periphery of the eyeglasses. The effect is due to the reflections of the edging that the finished and fit lens causes to converge within, depending on the edge thickness.

In order to reduce the weight and thickness at the lens edges, the only method adopted has been that of reducing the size of the actual lens – that is the "lenticular" portion in which the prescribed power is provided. The

remainder of the lens, the carrier, provides no refractive correction but gives dimension to the lens for mounting. These are the so called "lenticular lenses". The achieved reduction in weight and edge thickness is inversely proportional to the size of the lenticular portion of the lens. However, though lighter and thinner, lenticular lenses remain cosmetically unattractive because the central portion, which makes the eyes look fairly smaller, is clearly discernible within each ring of the eyeglasses as is the portion joining it to the carrier. This cosmetic dilemma has not been solved even by the so called "joint lenticular lenses" which feature a neutral or convex carrier and a round-shaped junction between the lenticular portion and the carrier. As a result of the round-shaped junction, the wide surface of the carrier takes on a high plus power in sharp contrast to the high minus power of the centre. Hence, a "tunnel effect" is produced which badly distorts the portion of the face which is covered with the lens. Lastly, the diameter of the actual optic area is insufficient to ensure viewing in all the natural directions of the gaze and forces the wearer to unnatural head postures in order to compensate for the limited freedom of movement of their eyes.

Disclosure of the invention

The lens design proposed solves the aforementioned technical problems. It is a single-vision or multifocal eyeglass lens for medium-to-high to very high nearsightedness in plastic, mineral or other suitable material, lighter and thinner at the edges and ensuring a wide field of vision. It is cosmetically attractive, manufactured as a finished or semi-finished lens,

featuring a spherical centre and an aspheric periphery, both asymmetrical to the lens optical centre (coinciding with the geometrical centre) and varying in width according to the power (central curvature of the lens) and the diameter (front width as viewed by an observer facing the eyeglass wearer) of the lens itself.

The find also covers all the procedures involved in the manufacturing of the lens, based on both non industrial and CNC processing and moulding and/or injection moulding techniques.

These are some of the benefits which will become apparent in the detailed description of the lens design proposed. The reference tables 1/5, 2/5, 3/5, 4/5 and 5/5 provide a lens manufacturing plan which is to be regarded as an example and is by no way restrictive.

<u>Way of carrying out the invention</u>

With reference to the above mentioned tables:

- Fig. 1 compares the prototype of a finished lens design (1) (right) to a conventional plano-concave lens (100) (left);
- Fig. 2 briefly illustrates the benefits of the asymmetrical lens surface during mounting;
- Fig. 3 reports some spatial projections of a surface calculation case;
- Fig. 4 and Fig. 5 illustrate the steps of the non industrial manufacturing process in the section of the lens along the reference diameter.

The following are the symbols in use in the figures (some more symbols will be added throughout the description):

C: optical and geometrical centre of the lens

DD': reference diameter. It is the axis of symmetry, horizontal to a front viewer.

AA': axis of the lens. It is the axis perpendicular to the reference diameter which passes through the centre (C). The lens is asymmetrical to AA' which, in turn, is vertical to a front viewer.

S: initial thickness of the lens. It is that of an ordinary 100 plano-concave lens (with a constant curvature), having the same DD', the same power φ (central curvature) and the same index of refraction (IOR) *n*.

Sc: centre thickness of the finished lens

Fig. 1 compares three projections of the lens design (1) to the projections of an ordinary plano-concave lens (100) with a constant curve.

On the right side of Fig. 1, the minus lens is subdivided into two areas (Fig. 1a). A centrally spherical area (2) is encompassed within the ZZ' diameter, which defines the refractive correction of the lens, and equals 70% of DD' in width. This area is wider in large diameter and medium-to-low myopic power lenses and smaller in small diameter and medium-to-high to very high myopic power lenses (small radiuses of curvature). Tangential to it is an aspheric area, which consists of a paracentral area (3) encompassing the spherical area (2), with a diameter equal to 10% of DD'. A peripheral area (4) encloses the paracentral area; it is tangential to the central, spherical area and stretches down to the lens edge. This is the flattest area which allows for the reduced lens mass and thickness.

The three areas are adequately connected in space, the intersection between a plane perpendicular to that drawn by diameters DD' and AA' and the back

surface of the lens being a polynomial curve which interpolates a set of accurately calculated points.

The end surface profile of the lens (1) (Fig. 1c) results from the summation of a series of portions of spherical surfaces. First, the diameter and the refractive correction of the lens are set: $\varphi = (n-1)/R$, where *n* is the refractive index of the material of which the lens is made and *R* is the radius of curvature.

The first surface, the one which corresponds to the central curvature, fit for providing the prescribed refractive correction, results from the intersection between the initial flat semi-finished material and a sphere with a radius R, the centre of which lies on the straight line passing through C and is perpendicular to the base of the semi-finished lens. The obtained profile is identical to that of a lens (100) (Fig. 1c to the left) with a constant curvature, an edge thickness S and a central thickness Sc.

The aspheric area of the lens is designed so that its axis is inclined with respect to the axis of the central area of an appropriate angle. By inclining the base of the semi-finished lens to make the final surface of the lens asymmetrical, the second and the following cuttings are made through a generally spherical surface Bn, the centre of which (Cn) lies along the half-line originating at C and having an inclination angle the radius Rn of which is correlated to the power of the peripheral area (φn), which is considered as constant. The centre Cn is extrapolated from the thickness S1 at the lens edge, corresponding to the extreme D of the reference diameter. S1 is a predetermined fraction of S. It follows that the

thickness S2 corresponds to D'. For instance, if S1 equals 60% of S, S2 will be about 75% of S (Fig. 1b).

The process continues in a similar fashion, so that that the spheres with radiuses varying between R and Rn (R1, R2,..., Rn-1) or with decreasing powers from φ to φn (φ1, φ2, ..., φn-1) cut the cusps between the various portions of the spheres that are formed at each repetition and, at the end of the process, the resulting surface is satisfactorily joint in space. The value of *n* can be regarded as a design constant or a parameter to be increased, should the number of repetitions be insufficient to yield the required accuracy, or decreased, should the obtained accuracy exceed that of the tool used to cut the lens, be it a non-industrial or an industrial tool (CNC cutting machine).

The concurrent action of the inclination of the axis of the aspheric periphery of the lens with respect to the axis of the centrally spherical area and the radial reduction in power towards the external edge of the lens contribute to making the lens surface asymmetrical with respect to AA' and causing a simultaneous, variable reduction in the thickness of the peripheral area. A

further consequence of the inclination of the axis of the peripheral area is its varying width along DD'. It is maximum close to the minimum peripheral thickness S1 and minimum at the maximum peripheral thickness S2.

The eccentricity of the peripheral area produces a gradual decrease in the central power of the lens with a subsequent reduction in the thickness at the edges. The advantage is that the points which are immediately adjacent to the central area (paracentral area) have a refractive correction close to that

of the central area. The thickness at the edges, S1 and S2 (Fig. 1b), is less than that of a 100 plano-concave lens having the same diameter, central thickness, refractive index and power. Hence, both the spherical and the aspheric areas are asymmetrical with respect to the centre C. The centrally spherical area ZZ' (Fig. 1a), the only one which retains the profile of the 100 plano-concave lens, stretches more to the left (CZ' portion) than to the right (CZ portion). The aspheric periphery is narrower to the left (D'Z' portion) than to the right (DZ portion). The surface curve variation which remains negative at all points is more marked along the DZ portion than along the D'Z' portion. The same power drop is reported along two segments (DZ and D'Z') and at two different heights, thus originating absolutely different profiles.

In section 1c, the end profile of the lens has been drawn, showing the amount of removed stock and the mitigated "coke bottle" effect when compared to the constant curvature lens (100). The angle δ' of the lens periphery (1) is smaller than the angle δ of any ordinary lens (100) – in which the prismatic effect causes the reflections of edging to converge towards the back side of the lens – and the reflections of the edging of the innovative lens are caused to converge outside the lens. In a front view, the lens (1) is thus free of the "coke bottle" effect which is typical of any minus power lens.

Fig. 2 documents the benefits of the asymmetrical surface of this lens design which complies, during mounting, with the interpupillary distance of wearers with a wide (Fig. 2a) or short distance (Fig. 2b). Being PP' the interpupillary distance, in the case of a wide interpupillary distance (Fig.

2a), it is advisable to cut the lens in such a way that, when the optical/geometric centre overlaps the pupillary centre P or P', the wider aspheric periphery coincides with the temple of the wearer and the narrower section with the nasal portion. By contrast, in the case of a short interpupillary distance (Fig. 2b), it is advisable to cut the lens so that the narrower section of the aspheric periphery coincides with the temple of the wearer and the wider section with the nasal portion. In both cases, the beneficial role of the asymmetrical surface of the lens is apparent. Regardless of the interpupillary distance of the wearer, the accurate centering of the eyeglasses is guaranteed. The central area (with a constant power) and the paracentral area (with a power close to the central one) cover most of the width of the outline of the eyeglasses and the wearer benefits from vision acuity in all the directions of the gaze, without having to resort to unnatural head movements, whereas the periphery, with a more marked power drop, lies at the extreme temple periphery of the eyeglasses, thereby diminishing the thickness and weight of the lens as well as the spherical aberration, which is typical of lenses with a small radius of curvature and high edge thickness, and nullifying the reflections of the lens edging.

As far as cosmetics and function are concerned, the aspheric surface noticeably improves the lens. The power drop, beside reducing the spherical aberration, also lessens the shrinking effect which is produced by the periphery, thus preventing any distortion of the face of the wearer covered with eyeglasses, as viewed from the outside.

Fig. 2 a and Fig. 2b are but general sketches. According to the prescribed power, the actual interpupillary distance, the selected frame and the desired cosmetic effect, the best diameter, the best aspheric shape of the lens and the portion of the periphery with a different power drop to be located at the temple can be selected.

The lens can be manufactured as a "semi-finished" or "finished" lens. The "semi-finished" lens is obtained from a blank (unfinished on both sides) which is finished on the back surface alone with a precise dioptric power. From this semi-finished lens a wide range of prescribed dioptric powers can be derived by finishing the front side in a spherical or toric fashion. The finished lens is obtained from a semi-finished lens, with the front side already conventionally finished with a given dioptric power. The back side is finished to give the lens the prescribed power. By adjusting some or all the design parameters (diameter, power, thickness at the edges along the DZ portion, width of the central area, central thickness of the finished lens, constant or repeatedly variable inclination of the half-lines on which the centres of the spheres which form the periphery lie) a vast array of profiles can be obtained.

Among the processing methods in use for this innovative lens design, noteworthy is the CNC machining which, thanks to the recent strides made in technological and industrial research, yields accurate free-form surfaces, while ensuring better optic quality and lower product costs. Fig. 3 reports some spatial projections of a numerically calculated surface. Fig. 3a shows a projection of the back surface of the lens onto the plane Π1 passing through the reference diameter (DD') and perpendicular to the axis (AA'),

highlighting the difference in edge thickness (S1 and S2) and profile and the general asymmetry between the right side and the left side with respect to the axis AA', perpendicular to the plane of the drawing. Fig. 3b shows a projection of the back surface of the lens onto the plane Π2 passing through the axis AA' and perpendicular to the diameter DD'. Fig. 3c shows a projection of the back surface of the lens onto the plane Π3 with a 25° rotation with respect to Π1 and a 10° inclination towards the viewer, so as to display the surface as a whole.

"Finished" lenses for the most common power intervals and "semi-finished" lenses (from which all prescribed powers can be derived) can be industrially produced for moulding or, in the case of thermoset plastic materials, for injection moulding in ready-made moulds. Should the find be industrially manufactured, reduced production costs would go hand in hand with accrued eyeglass customisation.

This innovative lens design can also be manually produced. Manufacturing would be more time-consuming, but undoubtedly cost-effective, given the limited piece of equipment required. A detailed description of the manufacturing process follows in Fig. 3 and 4 which show the section of the lens along DD'. This is but an example and it is in no way restrictive. Should anyone wish to manufacture a prototype of a minus power lens with a DD' = 70mm, a flat front surface, central thickness SC = 1mm and power expressed in dioptres $\varphi = (n-1)/R$ depending on the index of the selected material, the following values would apply: R = 50mm, n = 1.500, hence, $\varphi = -10D$. The semi-finished lens would have a front flat surface on which the reference diameter DD', the geometrical centre C and a central portion KK',

having a width equal to a predetermined fraction of DD', would be temporarily marked. KK' should preferably ≈ 65% DD' (Fig. 4a). The marking of KK' helps manufacture the aspheric periphery of the lens. Fig. 4b illustrates the first step, the so called "rough grinding" of the lens. Using a conventional surface generator, after clamping the semi-finished lens to the stand (10) which, in turn, is firmly locked to the generator, stock is removed from the back side of the semi-finished lens, thus generating a spherical surface or principal base Bp, which is expressed in dioptres and coincides with the power of the lens under grinding, e.g. Bp = -10. The depth of stock removal is selected so as to obtain the desired centre thickness Sc, e.g. Sc = 1mm. Stock removal based on Bp will also define the edge thickness S, which in this case would be 15 mm.

Then, (Fig. 4c) a surface having a Bs base or secondary base is generated as a predetermined fraction of Bp, preferably Bs ≈ 25% Bp, hence Bs = -2.50. During this second phase of grinding, the axis Ap of the principal base Bp is maintained inclined with respect to the axis As of the secondary base Bs at a corresponding angle α. As shown in Fig. 4c, in order to obtain the reciprocal inclination between Ap and As, a "prismatic ring" or wedge Δ is inserted between the lens and the generator chuck and oriented along the reference diameter DD', with its base towards D. The wedge gives asymmetry to the final surface of the lens. The Δ value (expressed in prismatic dioptres) of the wedge is a fraction of the thickness S as defined above – preferably $\Delta \approx 10\%$ S, in the case in point, $\Delta = 1.5$. The depth of stock removal to generate Bs should be selected so that, at D, the lens thickness becomes S1 ≈ 60% S, that is s1 = 9mm. As a result, at D', the side

opposite to S1, the lens thickness S2 is automatically defined. In the example, S2 = 11.25 mm, that is S2 ≈ 75% S. In addition, Fig. 4c shows that, owing to the prismatic ring, when defining the variable thickness along the lens edge, the base Bs varies in width. In the section of the main diameter DD' it reaches its peak width on the side of the minimum thickness S1 and drops to its minimum width on the side of the maximum thickness S2. Hence, the central portion of Bp is asymmetrical to the geometrical centre of the lens.

The next step of the process is called "lapping" (Fig. 5) and it draws the ultimate contour of the lens back side. A conventional lapping machine can be used to this end. After lapping both surfaces (Bp and Bs) with the appropriate spherical tools, having the same bases (Bp and Bs), lapping proceeds so that the tools with bases Bn, ranging between Bp and Bs, cut the cusps in between the various portions of the spherical surfaces which are generated at every stroke. A gradual transition from the lens edge to K is thus obtained, temporarily marked at the centre, with a satisfactory spatial connection. The calculations for selecting Bn tools and the amount of stock to be removed are referred to the area of the lens with thickness S1. It follows that typical values of the area corresponding to the thickness S2 are inferred. The sequential Bn value to be assigned to the base of the tool at every stroke is extrapolated from the arithmetical mean between the base of the reference portion of the surface and that of the externally adjacent portion. In the example, B1 = (Bp + Bs)/2 = 6.25; B2 = (Bp + B1)/2 = 8.12; B3 = (B1 + Bs)/2 = 4.37. The depth of stock removal of each base is such

that each stroke removes approximately half of the innermost reference surface.

As shown in Fig. 5a, in the lapping system, a rod P, through a ball-and-socket joint, ensures uniform distribution of pressure and freedom of rotation and transmits an oscillation to the lens which is kept flush with the tool (Bn). Hence, every time a spherical tool with a new base is used, the lens self-centres onto the temporary chamfer resulting from the intersection of the previously used bases and takes on a varying inclination $\alpha n < \alpha$. As a consequence, every newly generated surface portion is not concentric, but variously connected at every point, thus originating an overall aspheric surface, which is asymmetrical to the optical/geometrical centre of the lens.

It is worth underscoring that only some surfaces with major curvature differences have been highlighted in Fig. 5a. The number of required tools will vary with the desired accuracy, function and cosmetics of the lens. In order to eliminate any residual discontinuity at the periphery of the lens, an optional tool Bj can be used in a resistant but soft material (Fig. 5b), with a mean curvature with respect to the previously used tools. Given the type of material in use, the tool will take on the same outline of the periphery of the lens, as expected.

The last step of the process, "polishing", performed with very fine abrasives and following the same procedure adopted for lapping, completes the lens processing.